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## ANOMALY DETECTION USING A REMOTE GROUND VEHICLE

Pascal Kam

Rahul Kini

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## ANOMALY DETECTION USING A REMOTE GROUND VEHICLE

## ABSTRACT

A ground vehicle can be used to patrol a given area to detect anomalies, obviating the need for physical presence by a human operator. The ground vehicle can be remotely controlled by an operator that receives images from a camera on the ground vehicle. Alternatively, the ground vehicle can be fully autonomous such that it follows a pre-programmed path and uses a computer vision process to detect anomalies along its path.

## INTRODUCTION

Quality control of objects and processes in an industrial setting is integral to ensuring that minimum quality standards are met. Such a review process involves checking for anomalies on an object or in an area (*e.g.*, product errors or an obstructions in the area). This job is traditionally performed by a human, such as a person that performs a visual inspection of a product in a manufacturing process. However, in this example, requiring an in-person review can be prohibitive as there may be certain emergencies that prevent physical human attendance, thus potentially disrupting the quality control process.

As described in this paper, a remote-controlled or automated ground vehicle can be employed to obviate the need for a person to be physically present. The ground vehicle is equipped with a camera that stores or streams images to a remote location. In one example use, an operator can control the ground vehicle to traverse the area and capture images to be sent for review by the operator. For example, the captured images may include nearby objects, so that the images of the objects can be streamed to the operator and reviewed for anomalies in real-time or stored for such review at a later date.

In another example use, the ground vehicle can autonomously patrol the area and capture images. Such images are analyzed for anomalies using a computer vision program trained on a machine learning algorithm. In this example, no human is required during the review process as the vehicle is fully automated to perform the anomaly analysis.

In both cases, where an error or anomaly is detected, the location and type of anomaly is stored in a database. The location of the anomaly can include its location on the object as well as its location in the area. Such information can be used as training data for future computer vision anomaly detection or as educational material for training operators.

Further, the detection of an anomaly can send a notification to a different operator or computing system so that the issue can be addressed.

## DESCRIPTION

### Example Vehicle

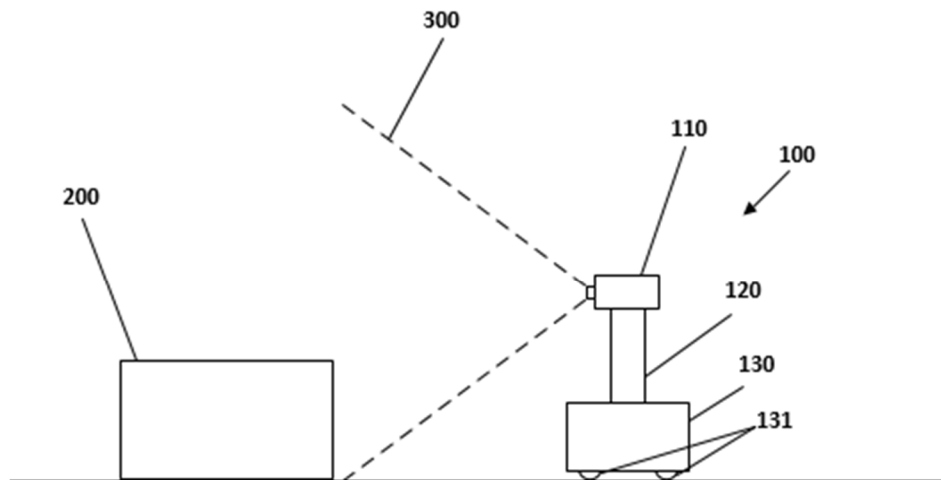


Fig. 1

FIG. 1 depicts a schematic view of an example vehicle 100 collecting images of object 200 located along the path of the vehicle. Vehicle 100 includes a camera 110, extension 120, and base 130. Camera 110 sits at an end of extension 120. Extension 120 extends from base 130. The

height of camera 110 can be remotely or automatically adjusted either by adjusting the position of the camera along extension 120 or by adjusting the length of the extension. In this manner, the height of camera 110 can change to accommodate the height of object 200 so that the object is within the camera's field of view 111. Where object 200 lies on the ground, as depicted in FIG. 1, the height of camera 110 can be lower. Conversely, where object 200 is higher, the height of camera 110 can be adjusted to be higher. Further, the angle of camera 110 with respect to extension 120 can be altered to achieve a similar purpose. Camera 110 includes camera functions known in the art, include zooming in and out, panning, rotating, and the like.

Base 130 can house the components that facilitates movement of vehicle 100, including wheels 131 and a motor operatively connected to the wheels. Further, base 130 can house a computing systems that provide instructions for moving vehicle 100 as well as for storing and transferring images received by camera 110. Such a computing device can locally store a computer vision program or be in wireless communication with a network that includes such a program.

#### Remote Access

Vehicle 100 can be remotely controlled by an operator to traverse a designated area. In this manner, an operator can be working from a remote location, such as from their home or off-site location, while being able to perform a quality check through vehicle 100. While vehicle 100 is being maneuvered, camera 110 can receive images within its field of view 111 to be streamed to the operator. The operator can manipulate camera 110 to change field of view 111 to get a better view of the area while moving vehicle 100. For example, the operator can maneuver vehicle 100 and camera 110 to observe objects in the area, such as object 200, as well as zooming in with the camera for a more detailed view. Such images can be streamed directly to the operator or stored in a cloud database for later use so that the operator can visually inspect the area for any anomalies

through vehicle 100 or for use as educational material to train operators (*e.g.*, for future installation and commission of components at active sites).

Anomalies can vary based on the context that vehicle 100 is in but, in general, anomalies are any abnormalities or errors in the field of view 300 of vehicle 100. In one example, anomalies can include any broken or misplaced parts on an object, such as object 200. This includes a bent or loose component. In another example, anomalies can include objects lying in the area that do not belong there and may prove to be a safety hazard.

Once an anomaly is detected, the operator can log the location and type of anomaly as well as send a notification to another operator or computing system of the anomaly information. After the operator or other computing systems have been notified of the anomaly, they can work towards resolving the issue, such as fixing the error on object 200 or moving it to a more appropriate location.

#### Automated Pathing

Vehicle 100 can be autonomously controlled by a computing system to patrol a designated area along a pre-determined path while using a computer vision program to detect for anomalies, as described above, when following that path. Here, the computing device can instruct the vehicle to patrol an area through a pre-programmed path and take images while patrolling. The computing system can adjust the position of vehicle 100 and camera 110, including through adjusting the field of view 111 by zooming in or panning with camera 110, to acquire an appropriate reference view for use with the computer vision program. Such images can be stored in a cloud database. Once the images are stored, they can be reviewed, used in a machine learning algorithm, and/or used as educational material to train operators.

The images can be reviewed by a computer vision program taken during its patrol contain any anomalies. For example, the computer vision program can cross-reference the images taken of an object during its patrol with an image of what a “correct” object looks like to determine whether there are any anomalies. If the image does not contain any anomalies, the computing system can instruct vehicle 100 to move on. If the image does contain anomalies, the computing system can log the location and type of anomaly and such information to a cloud database for storage. The computing system can also send a notification containing such information to an operator or another computing system to resolve the issue.

The images can be used as data in a machine learning training set to enhance both the accuracy of the computer vision program as well as the pathing of vehicle 100. A machine learning algorithm can use images from a cloud database to further train the computer vision program to better detect both the location and type of anomalies specific to a given area (*e.g.*, a manufacturing site or datacenter). This training can be performed in real-time, while vehicle 100 is patrolling, or uploaded into the computing system of the vehicle as an updated computer vision program later. Moreover, the frequency and location of the anomalies can be used to update the patrol path of vehicle 100 so that the vehicle can more frequently patrol the areas that are historically more prone to anomalies and that require more attention.

## EXAMPLE USES

Vehicle 100 can be used in a variety of contexts. In one example, vehicle 100 can be used in a manufacturing site. In this context, vehicle 100 can be remotely operated or autonomously controlled to detect whether products in the process of being manufactured contain any errors. Vehicle 100 can also detect whether anything in the manufacturing site can prove a hindrance to

the manufacturing process, such as inappropriately placed objects or malfunctioning manufacturing components.

In another example, vehicle 100 can be used in a datacenter. In this context, vehicle 100 can be remotely operated or autonomously controlled to detect whether any of the components of a datacenter, such as server trays, hard disks, or conveyor systems, have any visible malfunctions. Further, vehicle 100 can detect whether there are any obstructions or misplaced objects in the datacenter.